

FVS-EMAP: A Simple Tool for Displaying FVS Output in ArcView® GIS

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Abstract—The FVS Event Monitor ArcView® Project (FVS-EMAP) is a tool for moving simulation results from FVS into the ArcView® GIS. Using the customized ArcView® project, users can create maps depicting FVS output variables for a multistand landscape throughout simulated time. The tool can also display the maps in time sequence, thereby “animating” the landscape through simulated time. Users generate input for FVS-EMAP via the COMPUTE keyword (part of the FVS Event Monitor), and the *Compute2* postprocessor. An ArcView-based shapefile representing stand boundaries is required as a “template” onto which FVS-EMAP will map COMPUTE variable output. Besides functioning as an FVS postprocessor and landscape analysis tool, the project also contains a pre-processor that creates the supplemental record file (an FVS input file) associated with PPE keyword AREALOCs.

The focus of forest management has recently shifted from emphasizing stands to prioritizing ecosystems. “Landscape analysis” is now an integral part of forest management. Coincident with this shifting focus has been a surge of computing and geographic information system (GIS) technology. Early development of landscape-scale modeling tools within the Forest Vegetation Simulator (FVS) “family” of models began with the Parallel Processing Extension (PPE; Crookston and Stage 1991), which permits the simulation of stands altogether (in parallel) through simulated time—instead of serially (one stand after another)—thereby making possible the modeling of landscape-scale processes, such as pest contagion (see for example Beukema and others 1997). Other tools have been developed that extend FVS landscape analysis capabilities, including: Pre-Suppose, a preprocessor that assists users in retrieving data for groups of stands from a database (Vandendriesche, these proceedings); and the Event Monitor (Crookston 1990), a program within FVS that allows user to more easily schedule activities across a simulated landscape.

In this paper, we describe a new FVS postprocessing tool, the FVS Event Monitor ArcView® Project (FVS-EMAP), that helps users create maps depicting FVS projection output on a multistand landscape. Such landscape scale maps

can be useful for forest managers conducting landscape analyses using FVS.

In addition to being a postprocessor, FVS-EMAP can also be used as an FVS preprocessor to quickly generate the input data file associated with the FVS/PPE keyword AREALOCs. This supplemental record file contains geographical coordinates and areas of stands to be simulated. The FVS-EMAP extracts this information from an ArcView® shapefile (defined below) and writes it to a file, appropriately formatted for PPE.

Overview of FVS-EMAP

The FVS Event Monitor ArcView® Project (FVS-EMAP) is a customized ArcView® project (an *.apr* file) that simplifies the joining of FVS output data with a stand-based shapefile. A *shapefile* is ArcView’s native spatial data format and comprises at least three files, denoted by the extensions *.shp*, *.shx*, and *.dbf* (it may comprise more than these three files). Users having spatial data as ARC/INFO coverages, instead of as shapefiles, can easily convert the data to a shapefile format in ArcView®.

The FVS-EMAP is essentially a “blank” ArcView® project that differs from a standard ArcView® blank project in that it contains three additional scripts, written in ArcView’s Avenue® programming language, that have been compiled and embedded into the project. Each of these scripts performs a specific action or “function” (table 1). These functions are accessed via buttons on the project interface’s buttonbar (fig. 1).

Table 1—Descriptions of the three functions embedded in FVS-EMAP.

Function	What the function does:
1	(1) Prompts the user to locate a <i>.cp2</i> file—an FVS output file containing values of all Event Monitor COMPUTE variables; (2) prompts the user to locate a shapefile; and (3) joins the <i>.cp2</i> file output to the shapefile.
2	“Animates” the active View by displaying each Theme in the View one-at-a-time in two-second intervals, from top to bottom (which will be in chronological order if the Themes are positioned by Function 1).
3	Creates a supplemental record file for PPE keyword AREALOCs. The function: (1) extracts polygon areas, and x- and y-coordinates of polygon centers, and (2) launches an external program which will rewrite the extracted data into a text file, appropriately formatted for FVS.

In: Crookston, Nicholas L.; Havis, Robert N., comps. 2002. Second Forest Vegetation Simulator Conference; 2002 February 12–14; Fort Collins, CO. Proc. RMRS-P-25. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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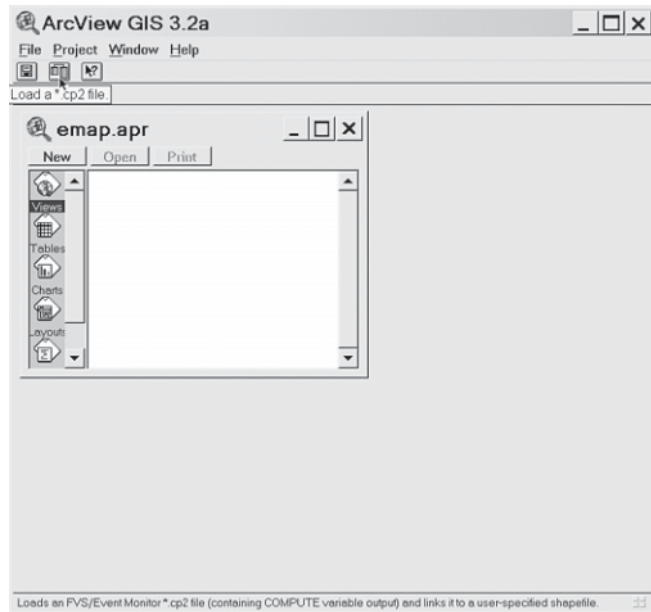


Figure 1—The FVS-EMAP project interface. The project interface resembles a typical “blank” ArcView® project. Note the “join” button and tool tip (at cursor, upper left), and the associated “help” information in the status bar (bottom).

Function 1 “loads” FVS COMPUTE variable output data (from a .cp2 file) and joins those data to a shapefile. It is designed to help the user quickly and easily make time-series map displays portraying FVS simulation output data. Function 2 “animates” the mapped data, portraying maps one-at-a-time in short intervals in such a way as to show how the modeled landscape might change over time. The third function, unlike the first two functions, is a preprocessor that extracts information from a shapefile and writes those data to a file to be used in an FVS simulation along with the FVS/PPE keyword AREALOCs. The bulk of this paper focuses on function 1, joining .cp2-file output with a shapefile; however, functions 2 and 3 are also discussed.

Using FVS-EMAP to create map displays of FVS output variables involves three basic steps (fig. 2). The first two steps occur at the FVS simulation set-up phase (before FVS-EMAP is launched).

The first step is to incorporate the FVS Event Monitor keyword COMPUTE, along with accompanying mathematical expressions, into an FVS simulation. This will generate the output to be mapped. The second step is to invoke the *Compute2* postprocessor, which rewrites the COMPUTE variable output to a form usable by the FVS-EMAP. The third step is running the custom ArcView® project, *EMAP.apr*. We only briefly discuss the first two steps; further information about the Event Monitor and the *Compute2* postprocessor can be found in Crookston (1990) and Van Dyck (2001), respectively.

To use FVS-EMAP, users must have: (1) standard FVS software and stand data files; (2) an appropriate FVS keyword file; (3) an ArcView® shapefile, which provides the information needed to map the boundaries of the stands being simulated; (4) ArcView® GIS software, version 3.2 or higher (currently available for all USDA Forest Service

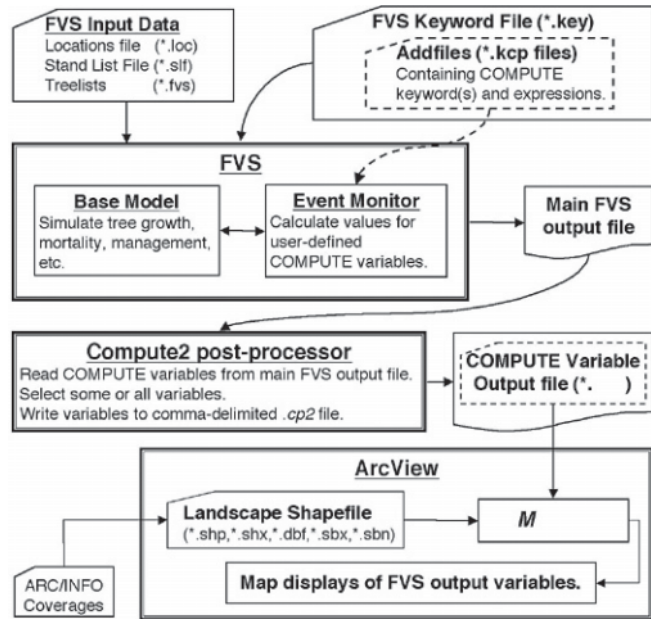


Figure 2—Flowchart diagramming the flow of information from FVS and the Event Monitor into the FVS-EMAP ArcView® project.

personal computers); and (5) the customized ArcView® project, *EMAP.apr*, available from the Forest Health Technology Enterprise Team (FHTET; contact information provided below).

Using the Event Monitor to Generate Input Data for FVS-EMAP

The COMPUTE keyword is an Event Monitor keyword that provides the user the ability to insert into an FVS simulation mathematical expressions that will be evaluated for stands throughout the simulation. The mathematical expressions incorporate predefined or previously defined Event Monitor variables. Users can use the COMPUTE keyword to have FVS report values of variables it (FVS) is already keeping track of (for example, basal area per acre); or it can be used to calculate elaborate user-defined mathematical expressions, such as a stand hazard rating scores or habitat suitability indices. For example, the map depicted in figure 3 depicts mountain pine beetle hazard ratings for stands as defined by Randall and Tensmeyer (2000). This hazard rating system was “coded” into the FVS simulation using COMPUTE statements and included for all stands in the simulated National Forest compartment. A number of such Event Monitor keyword component files (.kcp files, or “addfiles”) that calculate stand hazard ratings to various insect pests are available from FHTET. Also, packaged with FVS-EMAP is an addfile that generates output containing all of the metrics in the main FVS stand summary statistics output table, thus making these variables available to be mapped. Further details about using the Event Monitor to generate output variables of the user’s choice can be found in

Crookston (1990), as well as in the user's guides accompanying the FHTET-provided addfiles.

In conjunction with the COMPUTE keyword, the *Compute2* postprocessor must be used to generate a comma-delimited output file reporting the COMPUTE variables in a machine-readable format. The Compute2 postprocessor is available in Suppose (FVS graphical user interface). When included in a simulation, it automatically reads all COMPUTE variable output data (for all stands and all years in which it was generated) from the main FVS output file. It then rewrites the variables to their own comma delimited output file (a .cp2 file), organized by stand identification code (stand ID) and by year. This .cp2 file is the file that will be read in by FVS-EMAP. Further details about the Compute2 postprocessor can be found in Van Dyck (2001).

These features of FVS are used to generate the data for input into FVS-EMAP because:

1. The Event Monitor and the COMPUTE keyword can be used to access a large number of simulated tree, stand, and site variables.
2. The COMPUTE keyword allows users to mathematically manipulate any predefined or user-defined Event Monitor variable, thus allowing users to create a large number of *user-defined* variables, such as hazard ratings or habitat suitability indices.
3. The *Compute2* postprocessor reads all user-requested COMPUTE variables from the main FVS output file and rewrites them to their own comma-delimited output file (a .cp2 file). Having these variables written to their own file, comma-delimited, and indexed by stand ID and simulation year greatly facilitates the subsequent readability of the data by ArcView® GIS.

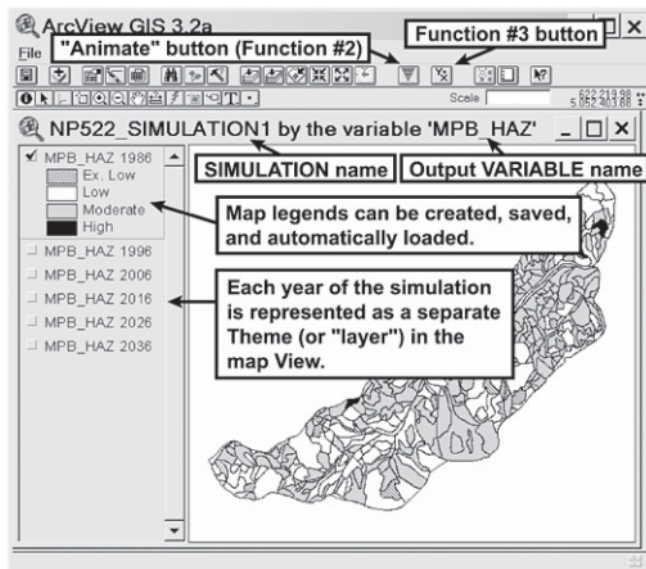


Figure 3—Example map View created via FVS-EMAP. The View will portray the FVS-simulated, user-chosen COMPUTE variable of interest on the user-provided shapefile. This map depicts mountain pine beetle hazard in 1986 for a National Forest compartment. There are map “layers” for each year in the output file. Predefined map legends, if installed, can be automatically applied.

Portraying FVS Data Spatially

After generating the desired FVS output data, the user launches the ArcView® GIS project *EMAP.apr*. The “blank” project interface will appear nearly identical to a “traditional” blank ArcView® project, except there will be at least one new button on the button bar (fig. 1). This button activates function 1.

Invoking function 1 begins the process of “loading” data from a .cp2 file into the project and “joining” the data to a shapefile. Once the user begins this process, the project will prompt the user for information. There are five main steps involved in the map-creation process. (The project may, however, provide more than the following five queries, depending upon how the user decides to have map legends created.) The five steps, outlined briefly here, and discussed below, are:

1. Input the FVS output data for analysis by “loading” the appropriate .cp2 file.
2. Input a stand-based shapefile containing the boundaries of the simulated stands.
3. Select an output variable to map.
4. Identify the field in the shapefile's .dbf table corresponding to the stand ID used in FVS.
5. Select a preformed map legend (if available), or begin the legend-creation process.

After the user responds to these five prompts, FVS-EMAP will create a map depicting the values of the output variable for the simulated stands. The map—actually a multi-Themed map View—will contain one map layer (a *Theme*) for each year reported in the .cp2 file (fig. 3).

For step 1, the project presents a dialog box prompting the user to navigate to the appropriate output file containing the data to be displayed. Typically this will be a .cp2 file. However, any appropriately formatted comma-delimited file is “readable” by the project. Additionally, the project can read in output files from the Westwide Pine Beetle Model (Beukema and others 1997), a landscape-scale bark beetle model extension to FVS.

For step 2, the project prompts the user to locate a stand-based shapefile containing the boundaries of the simulated stands. The user must provide the shapefile. The .dbf file associated with this shapefile must have a field containing data that are identical to the stand identification codes used in the FVS simulation. That is, the stand IDs used in FVS (which are the identifiers reported in a .cp2 output file) must have an identical counterpart in the shapefile .dbf. It is these matching stand identification codes that allow the project to join the .cp2 file output data with the shapefile (see step 4 below).

For step 3, the project will provide a list of all of the output variables that were read in from the .cp2 file. The user may create map displays for only one output variable at a time.

For step 4, the project will offer a listing of all of the column headings (field names) from the shapefile's .dbf table. The user must then identify the field name associated with the column of data containing stand identification codes. There must be a record for every stand reported in the .cp2 file. In other words, for every FVS-simulated stand, there must exist a polygon in the shapefile; the project will not allow the mapping of output onto a nonexistent polygon.

Step 5, the legend-creation process, can occur different ways depending upon what type of legend the user wants to use. If a preformed legend file exists (an *.avl* file, in a “Legends” subdirectory), with a filename matching the variable name being mapped, then the project will offer to use that legend. If no such corresponding preformed legend exists, or if the user declines using the preformed legend, then the project will create a legend. It offers the user the choice of creating a “unique values” legend (for use with discrete variables) or a “graduated” legend (for use with continuous variables). If a graduated legend type is chosen, the user is queried as to how many groups the data should be categorized into. The project then queries the user to choose a color scheme for the legend. Users can always “manually” edit legends in ArcView®. Once a desired legend is created, the user may save it to the “Legends” directory. If the new legend is given a filename that corresponds to a COMPUTE variable name, then it can be automatically applied by FVS-EMAP next time that COMPUTE variable is loaded and mapped.

After the FVS data View is created, two new buttons will appear on the project interface (fig. 3). One of these buttons will invoke the project’s second function: animating the display. Selecting this button begins the process of displaying the map layers one by one, in two-second intervals. This gives the user an animated “slices-in-time” view of the landscape, thus providing users a convenient way to see how the output variable changes over simulated time.

Generating an AREALOCs Supplemental Record File

The AREALOCs supplemental record file is a file needed by the FVS/PPE keyword AREALOCs. It contains data regarding the location and area of stands. The four fields of data in the supplemental record file are: Stand ID, x-coordinate of stand center, y-coordinate of stand center, and stand area. These data are not necessarily needed by the PPE but may be needed depending upon how one intends to use the PPE. If for example a user wants to run the Westwide Pine Beetle (WWPB) Model extension to FVS, keyword AREALOCs, along with its appropriately formatted list of supplemental records, is *required*.

The third function built into FVS-EMAP streamlines the procedure for creating this supplemental record file. Together with a separate FORTRAN program—*arealocs.exe* (which accompanies the FVS-EMAP package)—FVS-EMAP will create the supplemental record file containing coordinates of stand centers, and areas for all of the polygons (stands) in a shapefile.

Once a shapefile is loaded into FVS-EMAP and a View created (regardless of whether or not FVS output data are being portrayed), function 3 becomes available. This function:

1. Extracts stand centroid information (x- and y-coordinates of stand centers) and stand area from an ArcView® shapefile (note that the shapefile must be projected in a planar coordinate system, such as the Universal Transverse Mercator [UTM] System).

2. Optionally writes this information into the shapefile’s *.dbf* file.

3. Writes and saves a separate *.txt* file (comma delimited) containing only the four fields of data needed as supplemental records with keyword AREALOCs.

4. Then launches a Fortran executable program that reads the newly created *.txt* file and then writes the data, appropriately formatted, to a file.

This new file can then be used as an AREALOCs supplemental record file in a PPE/FVS simulation.

Summary

FVS-EMAP is a tool that can be used to make maps displaying results from FVS simulations on groups of stands. Its usefulness becomes more significant as a collection of stands representing a *landscape* is simulated. Once FVS output data are loaded into ArcView®, various spatial analyses may be performed (using the ArcView® Extension *Spatial Analyst*, for example). This allows users to address landscape-level and ecosystem-level management questions (for an example, see Smith and others, in these proceedings). Such ecosystem-scale and landscape-scale analyses are becoming increasingly important for forest managers, and tools such as FVS-EMAP are playing an increasingly important role.

The FVS-EMAP project software, documentation, and sample Event Monitor addfiles that calculate various stand statistics are available free of charge from FHTET at:

<http://www.fs.fed.us/foresthealth/technology/products>

or by contacting:

Forest Health Technology Enterprise Team
USDA Forest Service
2150 Centre Ave (NRRC), Bldg A, Suite 331
Fort Collins, CO 80526-1891
Attn: Eric Smith (elsmith@fs.fed.us)

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